RESEARCH PAPER

Predictive Performance of Different Diagnostic Criteria for Overweight and Obesity Between 2008-2015 in Adolescents

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Background: The reference cut-offs for overweight and obesity have evolved from the use of International obesity task force (IOTF) to extended IOTF and revised Indian Academy of Pediatrics (IAP) growth charts. **Methods**: Secondary analysis of anthropometric data of school-going children from Delhi in the year 2008, 2013 and 2015 was performed. The proportions of children with overweight, obesity, and undernutrition were checked for agreement using different diagnostic cutoffs, and compared at three-time points. **Results**: Among 8417 adolescents, weighted Kappa statistics showed good agreement between extended IOTF and IAP cutoffs (k=0.933; 95% CI 0.93-0.94), between eIOTF and IOTF (k=0.624; 95% CI 0.619 - 0.629) and between IAP and IOTF (k=0.654; 95% CI 0.645-0.662). A higher proportion of adolescents were diagnosed with obesity with extended IOTF and IAP charts than IOTF charts (P<0.001 for both genders). The mean (SD) BMI showed a rising trend for adolescents overall from 19.61 (3.89) kg/m^2 in 2008, 20.44 (4.37) kg/m^2 in 2013 and 20.88 (4.60) kg/m^2 in 2015 (*P*<0.001). 158 adolescent (97 girls) were undernourished using combined IAP and extended IOTF criteria. **Conclusion:** Both extended IOTF and IAP charts showed good agreement for diagnosing overweight and obesity in adolescents. A secular trend in malnutrition was observed in adolescent girls.

Keywords: *BMI, Extended IOTF, IAP growth charts, Secular trend, Undernutrition*.

Obesity has emerged as a pandemic across all age groups. Lifestyle including nutritional transition has been identified as a major risk factor for overweight and obesity in South-east Asia, including India [1]. A systematic review of 2416 population-based studies with 128.9 million children (5-19 years) showed plateauing of change in BMI from 1975-2016 in northwestern Europe, high-income groups of English speaking countries and Asia-Pacific regions, unlike east and south Asia which still showed an increasing trend [2]. In addition, undernutrition was listed among the top ten global contributors to disability-adjusted life years [3].This highlights the dual burden of over-nutrition and undernutrition in children.

Adolescents remain a vulnerable population for nutritional problems with their physiological and psychosocial changes [4]. The present study compares the performance of different diagnostic criteria for underweight, overweight and obesity in school-going adolescents from northern India over the last decade.

METHODS

A secondary analysis of previously collected cross-sectional anthropometric data of school-going adolescents (10-18 years) from five different zones (North, South, East, West, and Central regions) of Delhi in the last decade was done. Data were collected in 2008, 2013, and 2015 as three separate time points and not as longitudinal data (**Supplementary material**).

The schools were selected based on their geographical location and permission granted by the school managements. The detailed written protocol was provided to all parents through the school administration, requesting them to give written consent for their children to participate in the study. Assent was taken from the subjects before conducting the examination. Any child with a known chronic systemic disorder or taking any treatment for more than one month in the last three months based on school's medical records and parental proforma was excluded from the study. As per the education policy of Delhi Government, a mandatory 25% reservation for economically weaker sections (EWS) of students in schools was implemented with effect from 2011 [5].The ethical clearance was taken from the institutional ethics committee for the respective studies as done separately.

The anthropometric evaluations were made by trained

staff with subjects dressed in minimal light clothing and without footwear, as detailed before (**Supplementary material)**. Body mass index (BMI) was calculated as weight/(height)^2 in kg/m^2 and interpreted according to criteria given by the World Obesity Federation as International obesity task force (IOTF) [6], extended IOTF [7] and revised IAP growth charts 2015 [8]. The IOTF criteria defined overweight and obesity at six-monthly age intervals separately for boys and girls [6]. Overweight and obesity were defined as BMI more than ≥23 kg/m^2 and ≥ 27 kg/m^2 cutoff for respective age and gender interpreted at six monthly age interval in the extended IOTF classification [7]. IAP 2015 charts defined overweight as BMI ≥23kg/m^2 of adult equivalent (more than 71st and 75th percentile in boys and girls, respectively) and obesity as ≥27 kg/m^2 of adult equivalent (more 90th and 95th percentile in boys and girls, respectively) [8]. Undernutrition was classified as per extended IOTF as BMI less than 16 kg/m^2 of adult equivalent (thinness grade 3) [7] and as BMI less than 3rd centile (<-2SDS) as per IAP 2015 charts, separately for both genders [8]. The category of overweight was inclusive for obesity in all three definitions.

Statistical analysis: All statistical analyses were carried out using STATA V15.1 (StataCorp LLC). Data normality was checked by normal probability plot and Kolmogorov - Smirnov test. Undernutrition, overweight and obesity were compared between the groups by chi-square test. One way analysis of variance was used to compare the mean BMI between three different time points followed by Bonferroni correction for multiple comparisons. Weighted Cohen's Kappa coefficient was used to measure the degree of disagreement between the scales used. For testing of hypothesis two-tailed test was considered, and a *P* value of <0.05 was considered to be statistically significant.

RESULTS

Data of total 3401 boys and 5016 girls were evaluated across three time points. The weighted Kappa (95% CI) statistics showed good agreement between extended IOTF and IAP cutoffs (0.933 (0.93- 0.94); *P*<0.001), between eIOTF and IOTF (0.624 (0.619-0.629); *P*<0.001) and between IAP and IOTF (0.654 (0.645-0.662); *P*<0.001).

Using the combined criteria of extended IOTF and IAP charts (*n*=8417), undernutrition was seen in 158 (1.9%; 97 girls), overweight in 1809 (21.5%; 1137 girls) and obesity in 1300 (15.4%; 713 girls) adolescents. **Table I** shows the proportion of adolescents with underweight, overweight, and obesity for 2008, 2013, and 2015 for boys and girls as per three different criteria.

The mean (SD) BMI showed a rising trend for adolescents overall from 19.61 (3.89) kg/m^2 in 2008, 20.44 (4.37) kg/m^2 in 2013 and 20.88 (4.60) kg/m^2 in 2015 (*P*<0.001). The gender-wise mean (SD) BMI across these three years is shown in **Table II**. **Web Table I** shows age-wise BMI values across three years where significant secular changes were seen mostly between 10-15.5 year age-groups in boys, and in most age-groups in girls.

Table I Proportion of Underweight, Overweight and Obesity According to IOTF, Extended IOTF and IAP Criteria (2008-2015)

	2008	*2013*	*2015*
Boys	*n*= 1595	*n*= 1371	*n*= 435
IOTF			
Overweight	265 (16.6)	294 (21.4)	105 (24.1)
Obese	77 (4.8)	131 (9.6)	22 (5.1)
Extended IOTF			
Underweight	24 (1.5)	41 (3)	5 (1.2)
Overweight	350 (21.9)	335 (22.2)	119 (27.4)
Obese	209 (13.1)	305 (22.2)	75 (17.2)
IAP 2015			
Underweight	22 (1.4)	43 (3.1)	4 (0.9)
Overweight	298 (18.7)	277 (20.2)	108 (24.8)
Obese	243 (15.2)	352 (25.7)	86 (19.8)
Girls	*n= 1577*	*n= 1636*	*n= 1803*
IOTF			
Overweight	208 (13.2)	427 (26.1)	371 (20.6)
Obese	53 (3.4)	162 (9.9)	115 (6.4)
Extended IOTF			
Underweight	24 (1.5)	35 (2.1)	50 (2.8)
Overweight	374 (23.7)	472 (28.8)	471 (26.1)
Obese	144 (9.1)	370 (22.6)	296 (16.4)
IAP 2015			
Underweight	20 (1.3)	35 (2.1)	44 (2.4)
Overweight	338 (21.4)	456 (27.9)	440 (24.4)
Obese	122 (7.7)	321 (19.6)	273 (15.1)

All values in no. (%). P value calculated for gender-wise difference in proportion of nutritional categories for each respective year using each of the three BMI criteria separately. P <0.05 in 2008 and 2013 for all three criteria and in 2015 using extended IOTF and IAP criteria.

DISCUSSION

The present analysis demonstrated a good agreement between IAP 2015 and extended IOTF cutoffs for defining

Table II Body Mass Index of Adolescents (2008-2015)

	n	*Boys*	*n*	*Girls*
2008	1595	19.47 (4.03)	1577	19.74 (3.73)
2013	1371	20.11 (4.37)	1636	20.72 (4.36)
2015	435	20.36 (4.94)	1803	21.0 (4.51)

Data expressed as mean (SD). P<0.001 for year-wise comparison in boys and girls; P <0.05 for comparison between 2008 and 2013, and between 2008 and 2015, for both boys and girls.

WHAT THIS STUDY ADDS?

- Extended IOTF and IAP 2015 charts showed good agreement for detecting malnutrition in Indian adolescents.
- Mean BMI showed a secular trend in adolescents of both genders from 2008 to 2015.

overweight and obesity. A secular trend in obesity and overweight in the last decade (2008-2015) among school-going adolescents in northern India was also observed.

The lack of prospective longitudinal data was the main limitation of the study. Fewer boys in 2015 (as per school selection) and fewer adolescents stratified across different ages were difficult to be compared within subgroups for age-wise secular trends. The retrospective study design could not identify the effect of nutrition or socioeconomic status and associated risk factors for this trend.

The difference between old and new IOTF cutoffs was between -0.1 to +0.3 SDS when tested for data from China and the US-NHANES 20005 [7]. However, an earlier Indian study [9] showed double the proportion of obesity with the use of revised IAP growth charts than IOTF 2000 charts in both boys and girls, similar to the present study findings. The proportion of obesity as per revised IAP charts in boys in 2015 was marginally lower (16.2%) than the present study. The proportion of obese girls was lesser (5.8%), probably because of fewer representative girls in their study [9]. An excellent agreement between IAP 2015 and extended IOTF charts as seen in the present study was also shown earlier [10]. However, a difference in the proportions of nutritional categories between extended IOTF and IAP (even with excellent agreement) in the present study reiterates the need to use country- specific reference charts.

A secular trend in growth trajectories among children and adolescents has been documented globally [11,12]. A systematic review of 52 studies from India also reported an increase in the combined prevalence of overweight and obesity from 16.3% in 2001-05 to 19.3% in 2010 [13]. A pooled analysis on 2416 population studies (5-19 years) from 200 countries showed flattened BMI trends in Western countries, unlike South-East Asia where the prevalence of obesity increased from 0.9% and 0.7% in 1975 to 7.8% and 5.6% in 2016 in boys and girls, respectively [2]. The present study showed a significant rise in mean BMI in both genders in the last decade (2008-2015) as reported previously between 2006-2009 in New Delhi [14]. However, the proportion of obesity in both genders (and overweight in girls) showed a decline from 2013 to 2015. This implies that even though mean BMI showed a secular trend, the proportion of obesity reduced, which could possibly be due to increased awareness on obesity prevention in schools and communities, the impact of which cannot be deduced in the present study. Moreover, a longitudinal study design would have better substantiated the decline in burden of overweight/ obesity even though the mean BMI showed a marginal increase over time. The percentage of adolescent girls who additionally became obese (as per IAP criteria) from 2008 to 2015 was; however, higher than boys, which highlighted the gender-wise trend of over-nutrition in this study.

An increase in undernutrition from 2008 to 2013 (both genders) and in 2015 (in girls) in this study was probably because children from EWS category were admitted to 25% of seats in schools during these years. This may also be reflective of a nutritional transition where under-nutrition is increasingly being recognized in adolescents [3]. An increase in the proportion of undernutrition in girls with time was seen in this study, which highlights the need for nutritional strategies for adolescent females; the numbers of boys were meagre for a similar comparison. An overall declining proportion of children with moderate to severe underweight were reported globally albeit with India having the largest prevalence of underweight children. The mean BMI of adolescents (10-19 years) in south Asia were even lower than their African peers [2]. A modified BMI screening tool [15] has been recently validated to screen for undernutrition and over-nutrition in Indian children, which may help screen for dual burden of malnutrition.

The present study establishes a good agreement between extended IOTF and revised IAP charts to detect malnutrition. The need to identify both obesity and undernutrition as significant expansive health problems during school years with an emphasis on promoting healthy lifestyles in Indian children and adolescents is also highlighted.

Ethics clearance: No separate ethical clearance taken for the present analysis, IEC permission was available for all included studies.

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Note: Additional material related to this study is available with the online version at *www.indianpediatrics.net*

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Web Table 1A Body Mass Indices of Boys 10-18 Year Age Across Three Years

	2008 (N= 1595)		*2013 (N= 1371)*		*2015 (N= 435)*		***P value***
Age, y	*n*	*BMI, kg/m²*	*n*	*BMI, kg/m²*	*n*	*BMI, kg/m²*	
10-10.5	112	17.6 (3.6)	109	19.5 (4.3)	24	19.3 (4.4)	0.001
10.5-11	17	18.6 (3.6)	112	18.0 (3.5)	23	18.95 (3.4)	0.44
11-11.5	212	18.3 (3.6)	155	19.4 (4.3)	13	17.6 (3.4)	0.02
11.5-12	17	19.1 (3.6)	140	19.7 (4.4)	23	20.2 (8.8)	0.80
12-12.5	215	18.5 (3.5)	121	20.1 (4.3)	45	20.0 (3.7)	<0.001
12.5-13	18	17.2 (2.2)	138	19.9 (4.0)	40	19.0 (3.8)	0.02
13-13.5	225	18.7 (3.1)	108	20.4 (3.9)	27	19.9 (3.0)	<0.001
13.5-14	13	18.6 (2.8)	103	21.0 (4.6)	38	19.0 (4.7)	0.03
14-14.5	256	20.0 (4.2)	99	21.3 (4.6)	38	19.9 (3.0)	0.03
14.5-15	25	19.0 (3.3)	85	21.0 (4.4)	38	20.4 (4.0)	0.11
15-15.5	156	20.4 (4.4)	62	22.4 (4.8)	31	21.6 (4.1)	0.01
15.5-16	16	19.9 (3.6)	50	20.7 (4.1)	34	23 (8.7)	0.14
16-16.5	182	21.3 (4.4)	30	20.5 (4.8)	22	22.0 (4.6)	0.48
16.5-17	16	22.1 (5.2)	28	20.7 (5.1)	12	22.6 (4.7)	0.48
17-18	115	21.6 (4.2)	31	19.0 (3.7)	27	22.2 (3.9)	0.003

Data expressed as Mean (SD)

Web Table 1B Body Mass Indices of Girls 10-18 Year Age Across Three Years

	2008 (N= 1577)		**2013 (N= 1636)**		**2015 (N= 1803)**		**P value**
Age, y	*n*	*BMI,*	*n*	*BMI, kg/m²*	*n*	*BMI, kg/m²*	
10-10.5	84	18.0 (3.5)	195	19.2 (4.0)	53	17.0 (3.0)	<0.001
10.5-11	-	-	149	19.4 (4.0)	45	17.5 (3.5)	<0.001
11-11.5	217	18.1 (3.3)	195	19.6 (4.0)	88	19.3 (4.5)	<0.001
11.5-12	-	-	167	21.0 (4.1)	70	17.5 (3.3)	<0.001
12-12.5	236	18.8 (3.5)	152	20.4 (4.2)	140	19.8 (4.8)	<0.001
12.5-13	12	17.7 (3.4)	137	21.1 (4.3)	110	19.2 (3.5)	<0.001
13-13.5	242	19.6 (3.5)	111	21.5 (5.1)	152	21.1 (5.1)	<0.001
13.5-14	16	19.98 (3.4)	102	21.4 (4.2)	96	21.1 (4.3)	0.446
14-14.5	219	20.2 (3.6)	99	21.5 (4.1)	127	21.0 (4.1)	0.014
14.5-15	15	19.8 (3.5)	76	22.7 (4.4)	119	21.9 (4.0)	0.04
15-15.5	200	20.5 (3.5)	65	22.6 (4.6)	171	22.2 (4.4)	<0.001
15.5-16	19	21.5 (4.3)	75	21.6 (3.6)	117	21.9 (4.6)	0.86
16-16.5	182	21.1 (3.7)	62	23.0 (5.0)	142	22.2 (4.1)	0.003
16.5-17	26	21.9 (3.8)	23	18.7 (4.3)	99	22.9 (4.7)	<0.001
17-18	109	21.4 (4.0)	28	19.9 (4.2)	274	22.1 (4.4)	0.02

Data expressed as Mean (SD); -Less than five entries (data not computed)